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AN ANALYSIS OF PLANT FACTORS OF SOME LARGE STEAM PLANTS

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SUMMARY

This bulletin presents, possibly for the first time, a tabulation of the plant factors for 45 of the largest steam plants in the United States, based on reports submitted by the respective utilities to the Federal Power Commission. The need for this preliminary analysis and for further studies is explained.

There is also presented for reference, a set of curves showing the following plant factors over a period of 20 years:

1. For 38 plants included in study (over 20 years)
2. For all fuel plants in U.S. - From F.P.C. S-4
3. For all hydro plants - From F.P.C. S-4
4. For all plants in U.S. - From F.P.C. S-4

ACKNOWLEDGMENT

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AN ANALYSIS OF PLANT FACTORS OF SOME LARGE STEAM PLANTS

1. In the course of investigation by REA of the possibilities of building certain steam plants for war purposes, it was found that for the purpose of estimating the rational annual output and the cost per kilowatt-hour there was very little information available for the assumption of a rational plant factor. A preliminary study was therefore made of some of the data available in the Federal Power Commission as reported by the various utilities. It is felt that the result of this preliminary investigation will be of interest to other Government agencies.

2. Definitions in General

A great amount of confusion in engineering analysis is brought about by the fact that frequently the meaning of a term in an official definition has no direct relationship to the vernacular or dictionary meaning of the same term. In an engineering definition the term is a mere symbol. It would sometimes be better to use a letter symbol than a word. But once a term is accepted officially to mean a certain thing in engineering, every engineer should use the term in the sense of the official definition, otherwise engineering would soon become a Babel of languages.

On the other hand, while it is necessary to use accepted definitions, engineers, who create new definitions, should always consult the dictionary. It will make life less miserable for those who have to use the definitions.

3. Definition of the "Plant Factor"

According to the dictionary, the plant factor could mean anything relating to a plant, But the accepted ASA definition that everyone should try to follow is the one given in "American Standard Definitions of Electrical Terms" (published by the American Institute of Electrical Engineers - 1942):

> 35.10.126 - "PLANT FACTOR - The ratio of the average load on the plant for the period of time considered, to the aggregate rating of all the generating equipment installed in the plant"

It is important to note that the plant factor is based on "rating", meaning the rating given on the generator name plate and not on real or assumed capacity. For instance, if the rating is 5,000 kw at 80% POWER ~~plant~~ factor, the rating for plant factor purposes is 5,000 kw, even though the capacity may be 6,250 kw at 100% ~~plant~~ POWER factor.

In view of the fact that the plant factor is primarily a factor of business and economy and an index of the revenue from a kw installed or a dollar invested, the kw should be gross and the kwh net. The cost per gross kwh generated is of no interest. Only the cost per net kwh is of interest because only the net kwh produce revenue.

On the other hand the investment relates to the gross kw. Even that portion of the capacity that is used for auxiliaries calls for investment. Therefore, in the definition of the plant factor, the rating should be gross kw and the energy net kwh.

For a normal year, having 8,760 hours, the annual plant factor, in percent, is:

$$\frac{100 \times \text{Net kwh Generated}}{8{,}760 \times \text{Gross Capacity of Plant in kw}}$$

For a leap year, having 8,784 hours, the annual plant factor, in percent, is:

$$\frac{100 \times \text{Net kwh Generated}}{8{,}784 \times \text{Gross Capacity in kw}}$$

4. Explanation of the Plant Factor

A power house of 1-kw capacity, without being overloaded, cannot generate more than 8,760 kwh gross in a normal year nor more than 8,784 kwh gross in a leap year. Some of the energy so generated is consumed for operating motors that drive water pumps, coal handling equipment, exciters, battery charging units, etc. So that all the 8,760 kwh generated in a normal year are not available for sending out to consumers. Older plants consume perhaps 5 percent for the auxiliaries. Some modern steam plants using powdered fuel consume as much as 12 percent for the auxiliaries. Assuming 5 percent for auxiliaries, the maximum net energy available in a year from a plant of 1-kw capacity, without at any time overloading the plant, is 8,760 less 5 percent, or 8,322 kwh. It is thus evident that a plant factor of 100% is impossible in practice because of the energy consumption by the auxiliaries.

If the plant actually sent out 8,322 kwh to consumers in any one year, the plant averaged in that year its highest possible plant factor--95 percent. If only half as many kwh, or 4,161 kwh, were sent out in one year, the plant averaged in that particular year a plant factor of 47.5 percent. If only 25 percent of the total possible net kwh, or 2,080 kwh, were sent out in one year, the plant averaged in that year a plant factor of 23.75 percent.

5. Do Not Confuse "Plant Factor" with "Load Factor"

Since this confusion still frequently appears in the engineering literature, it is important to again clarify the difference. The load factor is the ratio of the average load over a period, say a year, to the peak load during that period. It has no relationship to the capacity of the plant and hence no relationship to fixed capital, fixed charges, or the degree of use to which the plant has been put during the year. A plant may have a capacity of 100,000 kw. In one year it may have had an average load of 45,000 kw, a peak of 90,000 kw, and hence an annual load factor of 50 percent. In another year the same plant may have had an average load of only 4,500 kw and a peak of only 9,000 kw. The annual load factor would

also be 50 percent. A low load factor will generally bring about a low plant factor, but other causes may also bring about a low plant factor.

6. Significance of Plant Factors

While the plant factor has been recognized by most competent engineers as the most important factor in power economy analysis, as well as in estimating future capacity requirements, its incompetent use has been one of the principal causes of faulty estimates. In recent discussions of power capacity shortages and power capacity requirements, as well as in the dispute of water power versus fuel power, it has been one of the most important causes of the confusion. In estimating the cost of generation by steam and in the arguments that steam is more economical than water power, only fuel savings are generally reported. The fixed charges may be a more important item of cost than fuel and all other operating expenses combined. The fixed charges for net kwh depend on the average number of kwh the plant is expected to send out to consumers throughout its expected life, not only in one year. By selecting a suitable plant factor, the cost for kwh can be made to come out almost anything at all in the estimate. Assume a 100,000 kw modern steam plant to cost $100.00 per kw and to have 10 percent fixed charges. Thus the fixed charges per annum per kw would be $10.00 or 10,000 mills. Assume that the plant could have an average plant factor of 100 percent throughout its life, say 20 years, each kw of its capacity would send out to consumers every year, for 20 years, 8760 kwh (forgetting the existence of leap years). The total fixed charges per year being 10,000 mills, the fixed charges per net kwh would be 1.14 mills. Such assumption would be ridiculous on the face of it. First of all, a modern steam plant, burning powdered fuel, will consume perhaps 12 percent for station auxiliaries. So that the net kwh, even in one year, cannot possibly be 8,760 kwh; they could not possibly be more than 7,709 kwh and the plant factor even in one year could not possibly be 100 percent. It could not be over 88 percent.

Furthermore, it is not reasonable to assume that every boiler, turbine, pipe, cable and wire will operate at full capacity for 20 years every minute of the day or night. If one thing or another is not being taken apart all the time for inspection, cleaning or repairing, the steam plant will not last 20 years, probably not even 10 years. So that for such a plant even an assumption of 80 percent average plant factor over 20 years is not practical. Assuming an average plant factor of 50 percent, the fixed charges per kwh at once becomes 2.28 mills instead of 1.14 mills.

7. What Is a Reasonable Assumption for the Plant Factor of a Steam Plant

No data are available for assumptions. It would be necessary to know how similar plants operated in the past over a period equal to that of the assumed life. It would be necessary to know what the past load curves looked like. Then it would be necessary to estimate what the future improvements in design will be and the future load curves will look like. Many a steam plant that was originally built as a base load plant and operated over one year or 5 years with a plant factor of 60 percent is no longer a base load plant because a much more efficient plant has since been

built on the system and the original plant now operates with a plant factor of perhaps only 15 percent, or less.

The national averages shown in the curves include all the obsolete, as well as all the most modern plants. It would, therefore, be unwise to use a figure from the curves for estimating purposes without a thorough familiarity with many features relating to the specific plant under consideration.

It is of interest to note that over a period of years the average plant factors of the larger steam plants considered in the attached tabulation are lower than the national average for all steam plants. An explanation of this astonishing revelation is not attempted here, nevertheless the fact remains a fact.

In one respect the national average curves are quite significant. They show that hydro plant factors are persistently higher than steam plant factors, that on the average more kwh are gotten out per kw of installed hydro than per kw of installed steam. This is sufficient evidence that any effort to show that on the whole steam plants are more economical than hydro because fuel efficiency has been improving is inconsistent.

The accompanying tabulation is believed to be of the first of its kind. Since the tabulated plants were selected at random from the Federal Power Commission files, no plant names have been shown. Whenever the net kwh were definitely known as such, they were used in the computations. In some cases it was not definitely known whether the reported kwh are gross or net. In such cases it was assumed that they are net, and the real plant factor may be lower than those given in the table. It is hoped that this tabulation will help the engineer make more reasonable assumptions. It certainly should help eliminate assumptions of plant factors of 100 percent, 80 percent, or even 60 percent over the whole assumed life of a steam plant. It is hoped that it will be possible to continue this study and accumulate more data.

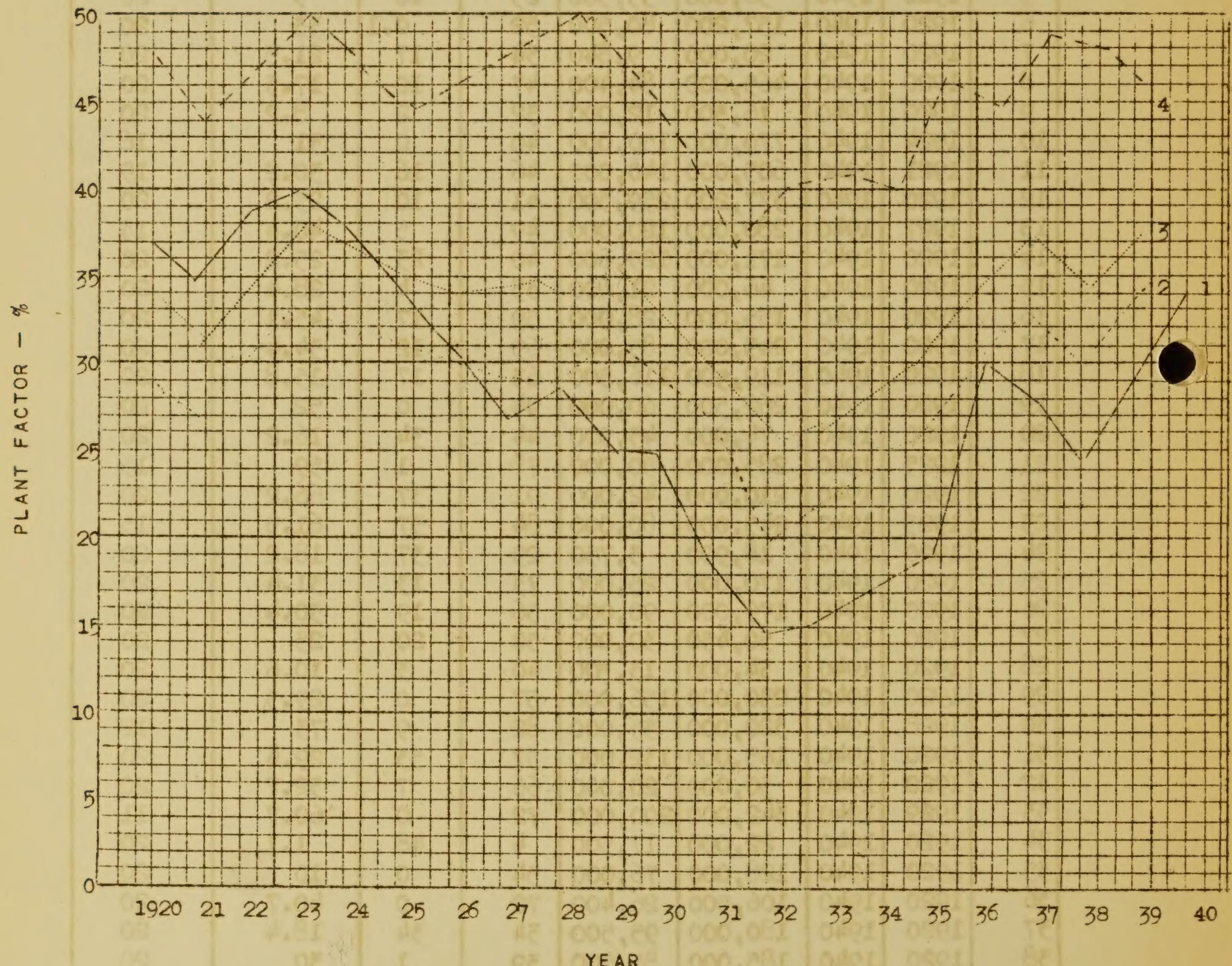
PLANT FACTOR OF LARGE STEAM PLANTS
(FROM F.P.C. DATA)

Plant No.	Years Reported From	To	Capacity During Period Maximum	Minimum	Plant Factors - Percent Highest	Lowest	Weighted Average	Period Years
1	1920	1940	231,000	108,000	39	17	24.6	20
2	1920	1940	30,000	24,000	11	0	1.4	20
3	1920	1940	55,000	32,600	19	0	9	20
4	1920	1940	57,000	50,740	30	0	17.8	20
5	1920	1940	38,000	33,500	23	10	9	20
6	1920	1940	157,200	80,500	52	0.1	33	20
7	1920	1940	20,000	9,840	34	17	21.5	20
8	1920	1940	465,000	84,400	47	10	17.5	20
9	1920	1940	16,500	12,000	32	2	8.2	20
10	1924	1940	770,000	150,000	40	0	31	16
11	1921	1940	605,000	140,000	46	16	30.2	19
12	1920	1940	377,200	259,500	41	10	25.2	20
13	1927	1940	280,000	120,000	49	5	40.4	13
14	1920	1940	171,000	129,600	40	23	25.2	20
15	1920	1940	46,000	21,600	35	4	28.4	20
16	1920	1940	155,000	28,000	59	17	45.1	20
17	1920	1940	243,000	85,000	65	12	34.4	20
18	1920	1940	119,500	116,500	63	17	15.8	20
19	1920	1940	262,500	60,000	94	0	52	20
20	1920	1940	74,000	43,500	44	34	16.2	20
21	1925	1940	285,000	50,000	78	1	59	15
22	1920	1940	210,000	42,000	91	37	66.2	20
23	1925	1940	245,000	80,000	84	37	61.5	15
24	1920	1940	18,900	3,750	29	37	18.2	20
25	1920	1940	170,000	25,000	73	13	31.4	20
26	1920	1940	179,000	90,000	56	19	30.4	20
27	1920	1940	50,450	30,000	50	20	25	20
28	1920	1940	34,000	13,500	40	3	10.6	20
29	1920	1940	230,000	156,000	57	0	29.5	20
30	1928	1940	320,000	55,000	82	9	73	12
31	1920	1940	165,000	132,000	57	53	29.4	20
32	1920	1940	50,000	20,000	66	7	32.7	20
33	1929	1940	342,000	200,000	72	0	60.7	11
34	1920	1940	22,000	17,500	4	48	1.1	20
35	1920	1940	128,000	76,000	54	0	10	20
36	1920	1940	106,500	26,400	72	0	40.7	20
37	1920	1940	180,000	95,500	34	34	18.4	20
38	1920	1940	185,000	85,500	39	1	30	20
39	1920	1940	240,000	60,000	71	21	56.5	20
40	1920	1940	36,000	10,000	55	42	29.1	20
41	1920	1940	81,500	18,000	31	23	22.7	20
42	1920	1940	92,500	32,000	51	18	14	20
43	1920	1940	82,500	15,500	52	2	33.6	20
44	1920	1940	38,000	18,000	45	23	21.5	20
45	1925	1940	75,000	35,000	59	1	36.5	15
Overall average (plants reporting 20 years only)							32.1	

PLANT FACTOR DATA

NATIONAL ANNUAL AVERAGE

1. For 37 Plants included in study (Reporting over 20 years)
2. For all fuel plants in U.S. - From F.P.C. S-4
3. For all plants in U.S. - From F.P.C. S-4
4. For all hydro plants - From F.P.C. S-4



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